

RADIATION DAMAGE IN ZRC AND ZRN

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MATERIALS

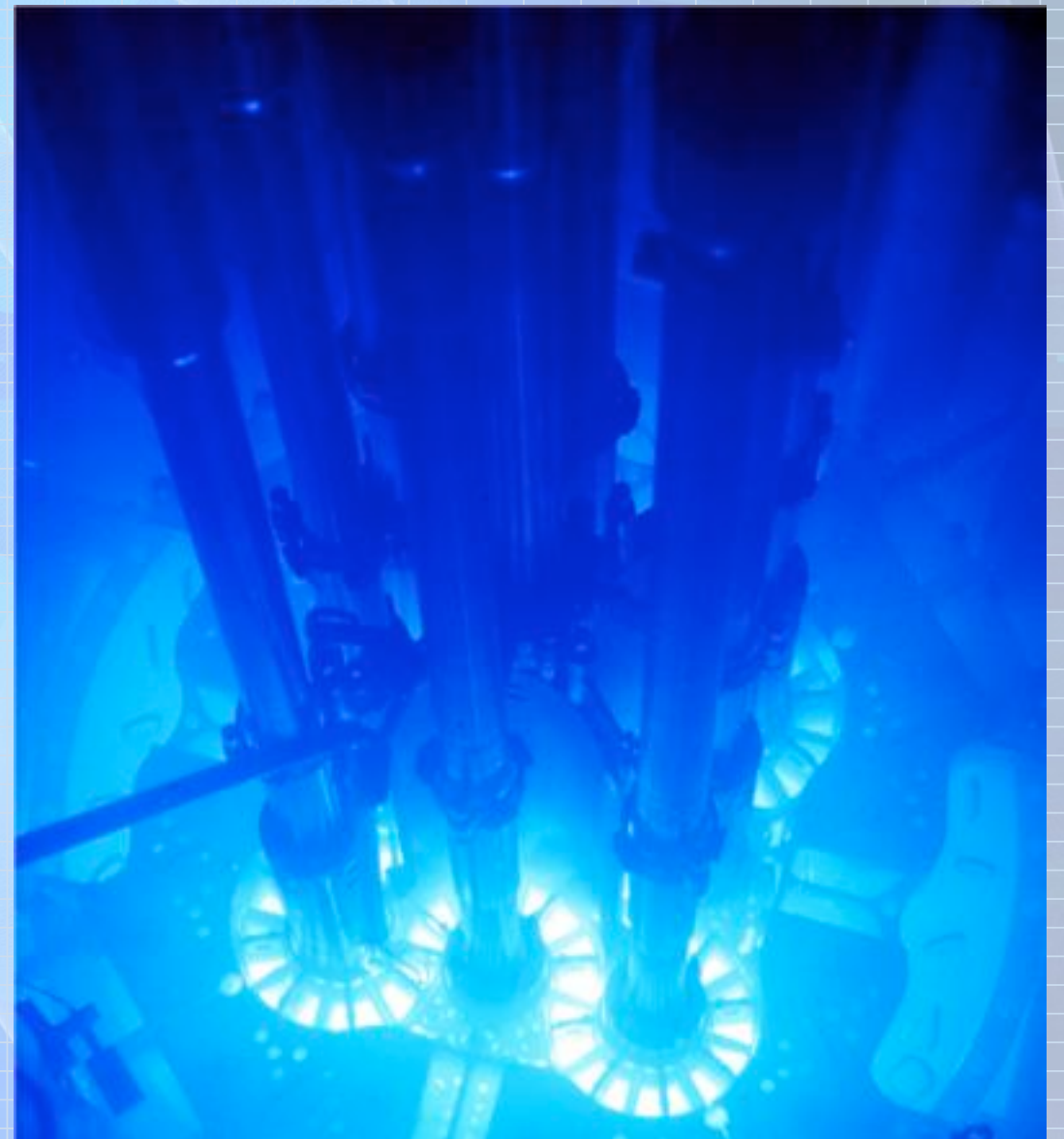
- ▶ REACTORS MATERIALS ARE OLD
- ▶ MANY DEVELOPED IN 1940s AND 1950s
- ▶ TIME FOR NEW MATERIALS
- ▶ CANNOT IRRADIATE TO 100s OF DPA
- ▶ SCIENCE BASED UNDERSTANDING OF RADIATION DAMAGE

PARTNERSHIP BETWEEN IIT AND ADVANCED TEST REACTOR

- ▶ **PROVIDE NUCLEAR COMMUNITY ACCESS TO
SYNCHROTRON RADIATION TECHNIQUES**
- ▶ **RADIATION DAMAGE**

ADVANCED TEST REACTOR

- ▶ CUTTING EDGE RESEARCH IN HIGH TEMPERATURE AND RADIATION ENVIRONMENTS
- ▶ IMPROVED PERFORMANCE OF CURRENT AND FUTURE LIGHT WATER REACTORS
- ▶ BASIC AND APPLIED RESEARCH PROJECTS



SYNCHROTRON TECHNIQUES

▶ ELECTRONIC STRUCTURE

- ▶ PHOTOELECTRON SPECTROSCOPY

- ▶ X-RAY ABSORPTION NEAR EDGE SPECTROSCOPY

▶ GEOMETRIC STRUCTURE

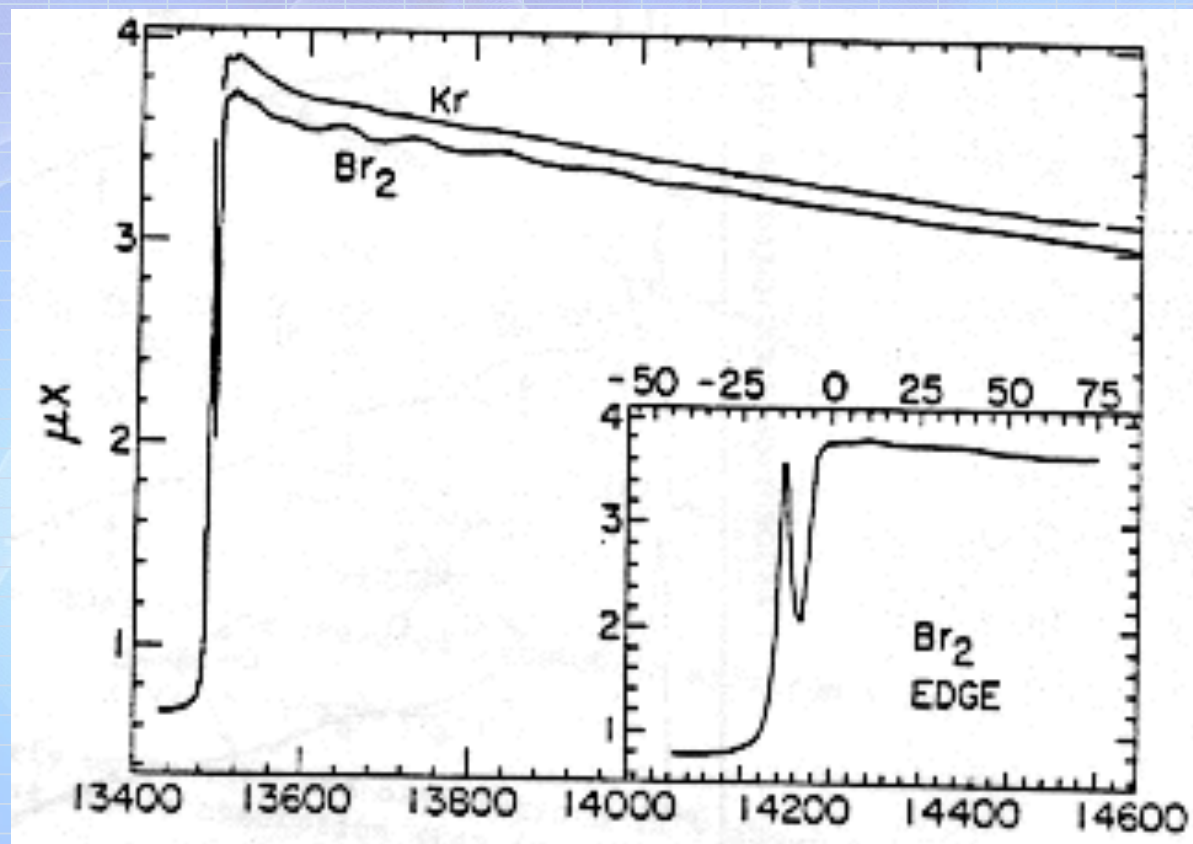
- ▶ EXTENDED X-RAY ABSORPTION FINE STRUCTURE

- ▶ X-RAY SCATTERING

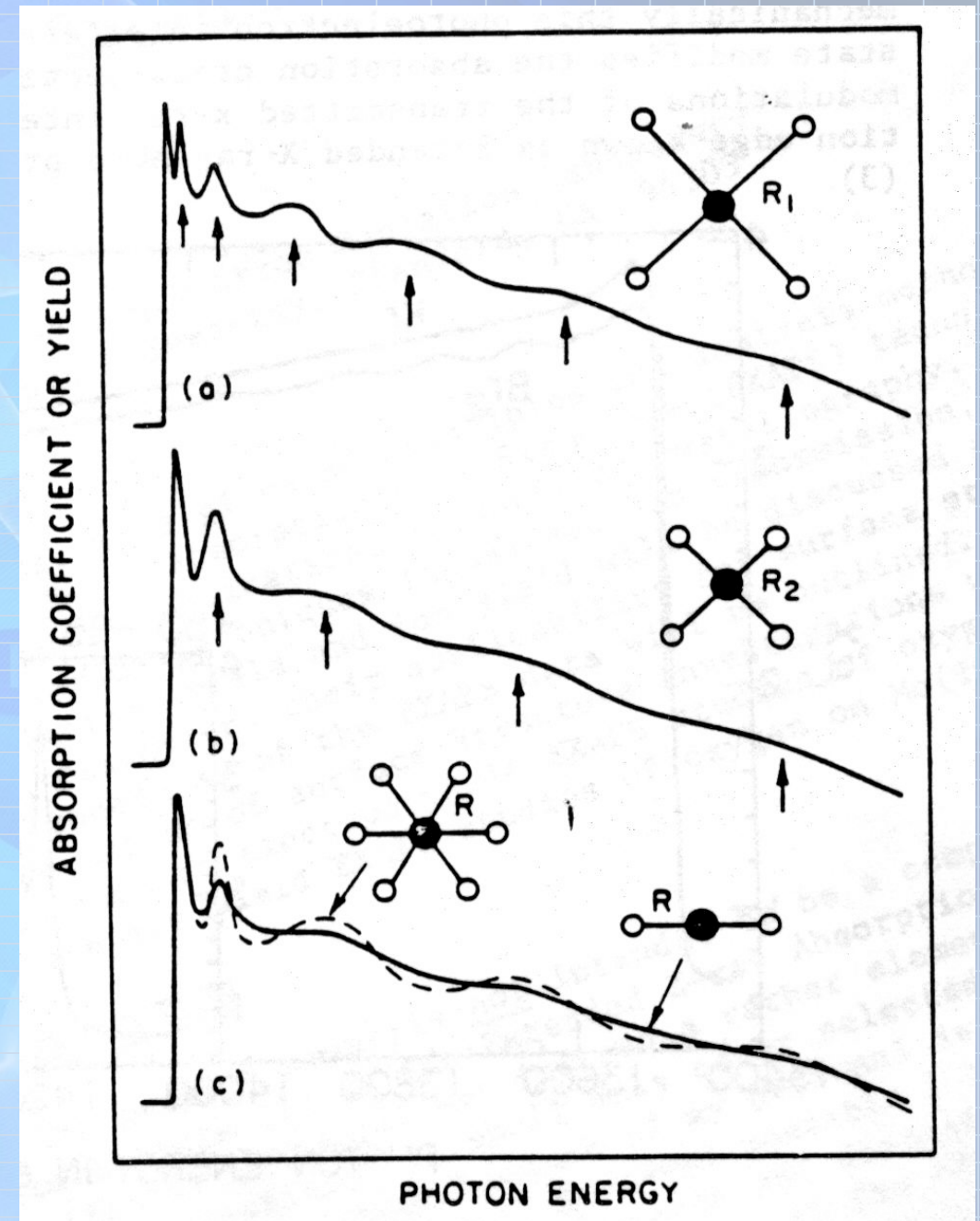
ADVANCED PHOTON SOURCE



X-RAY ABSORPTION



J. STOHR NEXAFS SPECTROSCOPY

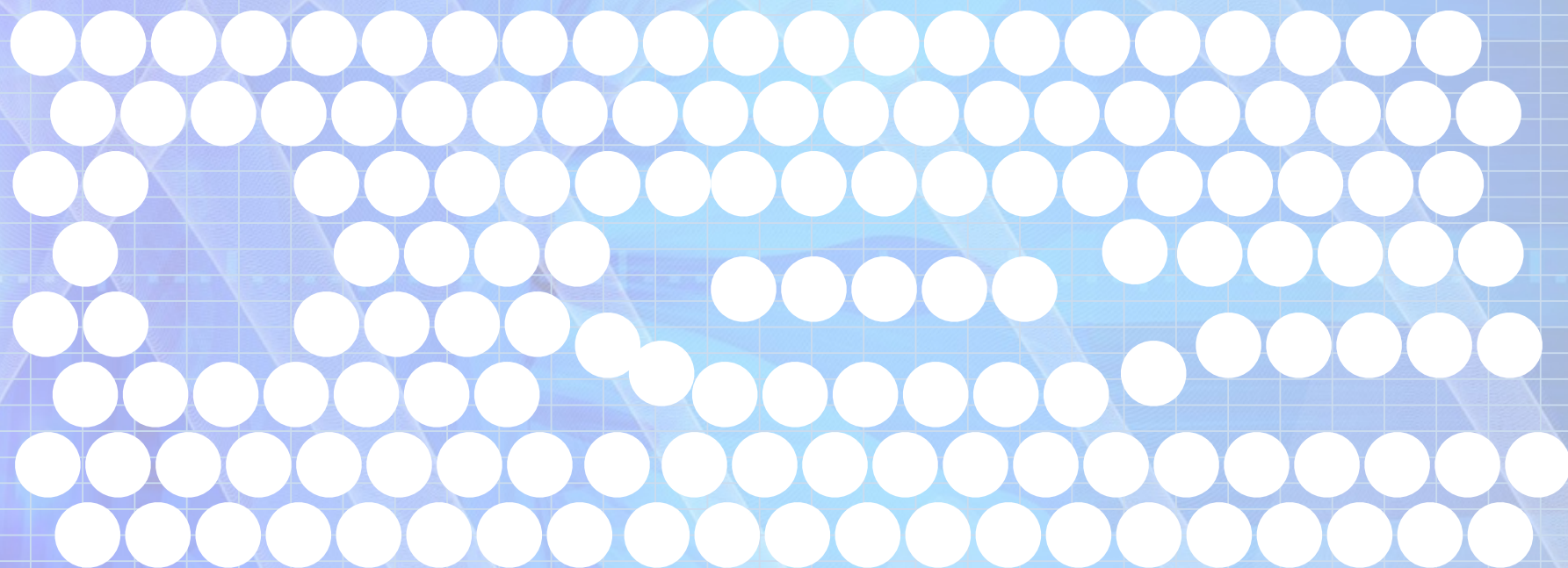


► GEOMETRIC STRUCTURE

► EXAFS

► INTERFERENCE BETWEEN EMITTED AND SCATTERED ELECTRON WAVES

REDUCTION



▶ DEFECTS REMOVE NEIGHBORS

ATR NSUF

▶ ATR SAMPLE LIBRARY

- ▶ TIC, TIN, ZRC, ZRN, SIC, ALC

▶ IRRADIATIONS

- ▶ 0 DPA

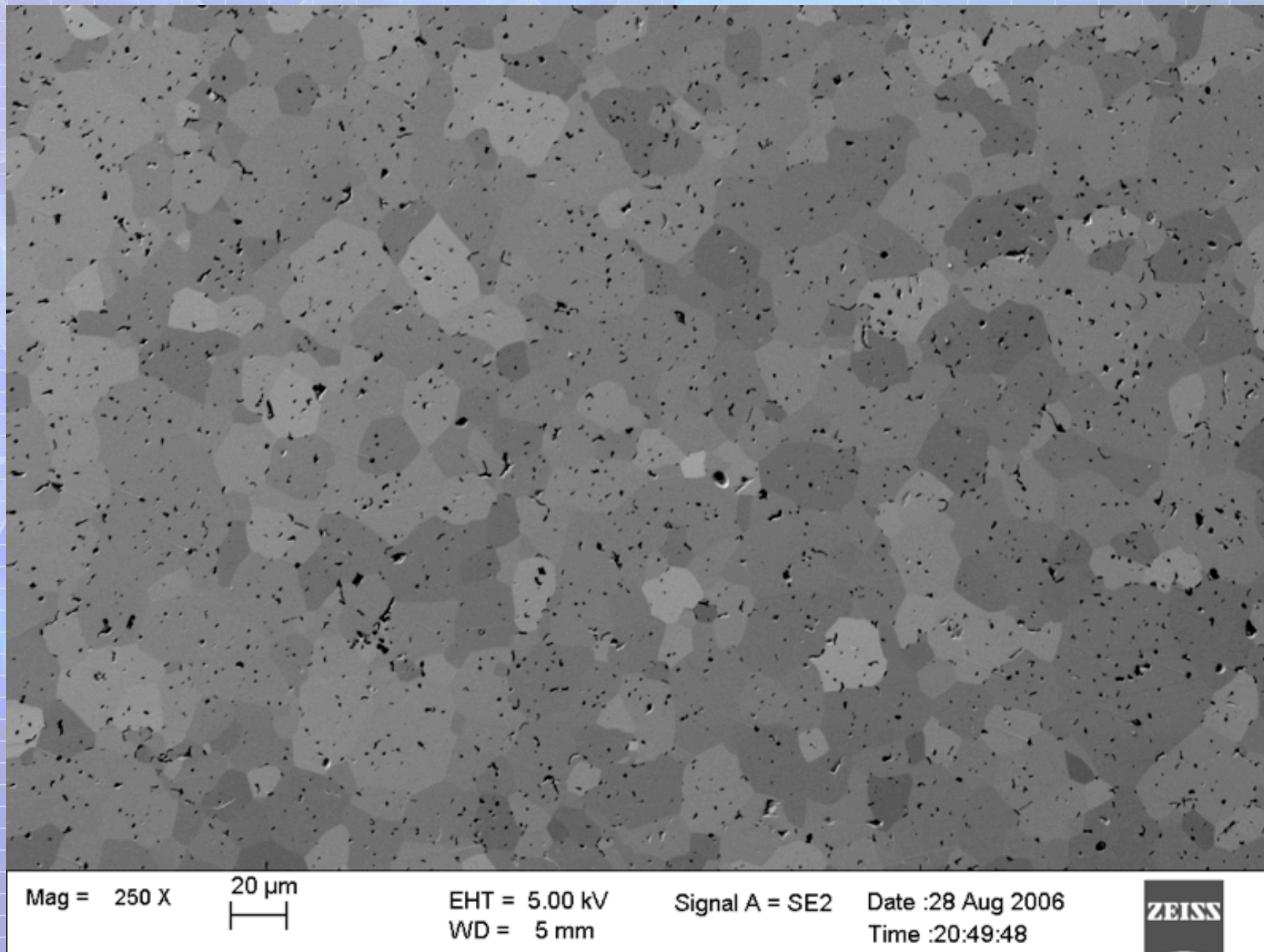
- ▶ 1 DPA @ 800 °C

▶ PROJECT AWARDED 6 SHIFTS OF BEAMTIME

- ▶ ZRC AND ZRN

- ▶ XAFS

ZRC

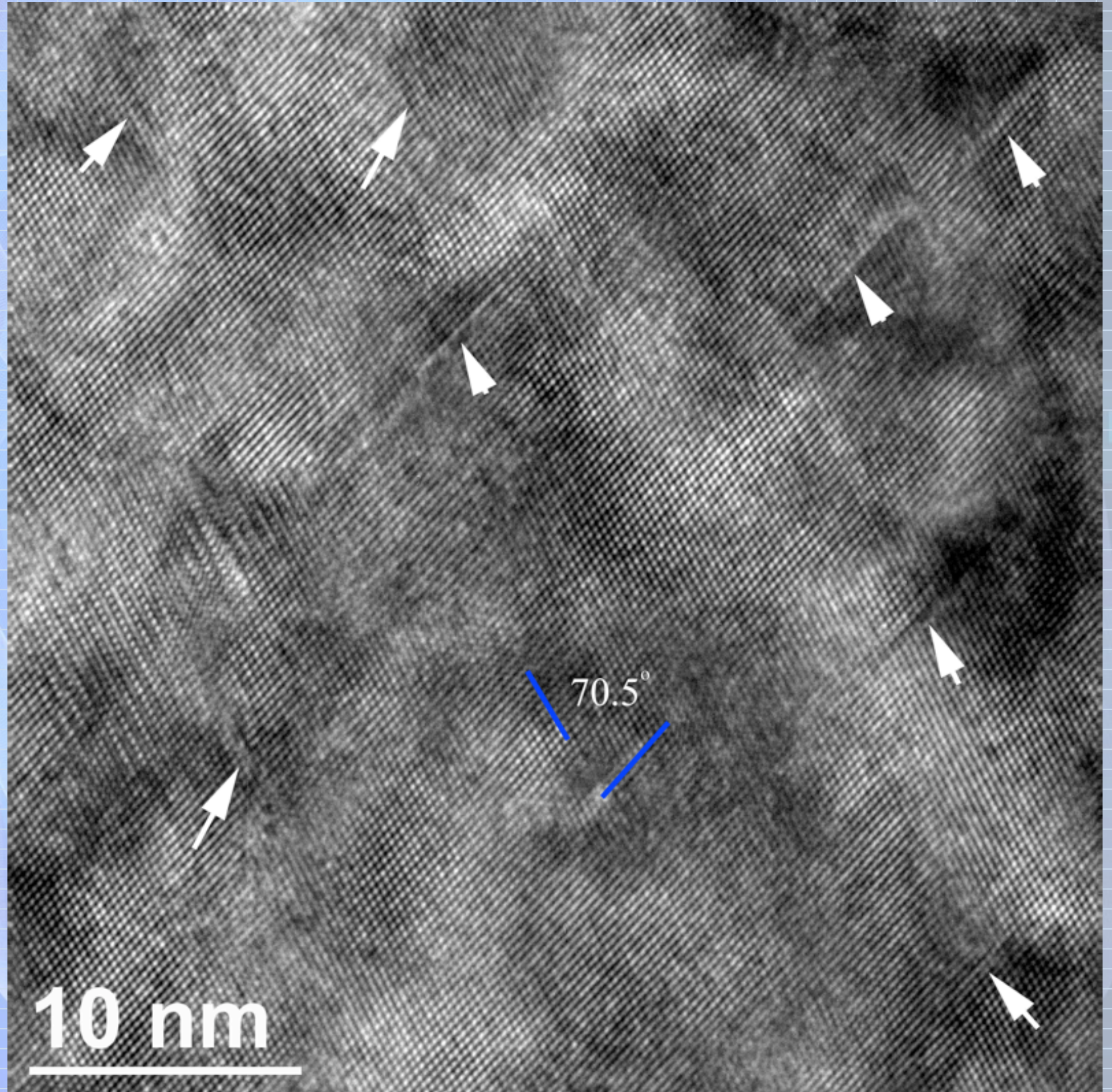


► SEM → UNIRRADIATED GRAIN SIZE ~ 24 μ m

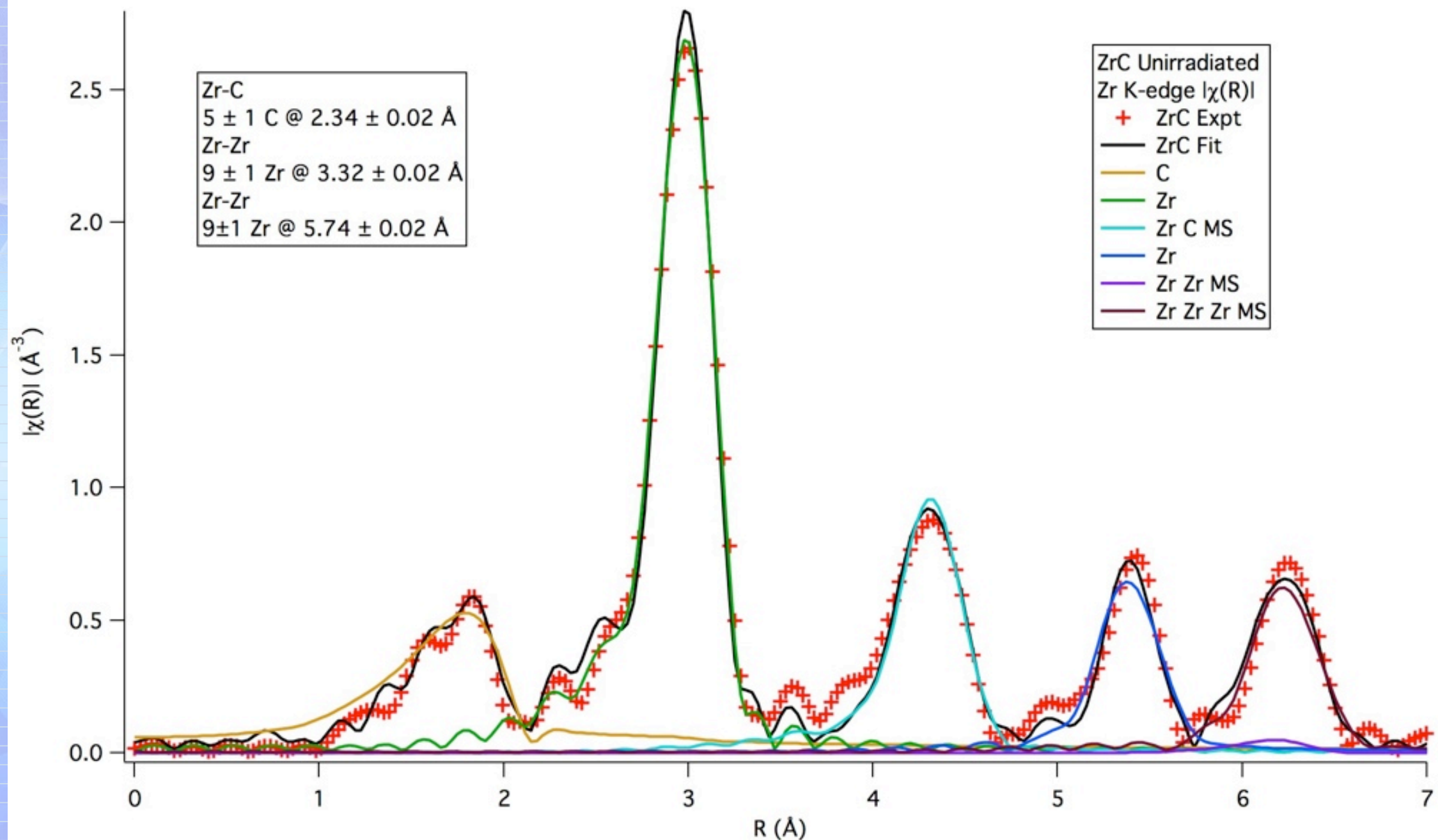
► IMAGE YONG YANG UW/ANL

ZrC

- ▶ DISLOCATION LOOPS
- ▶ TEM - PROTON IRRADIATED 1.5 DPA @ 800 °C
- ▶ WHITE ARROWS EDGE-ON DISLOCATION LOOPS ON (1 1 1) PLANES
- ▶ ANGLE BETWEEN THE EDGE-ON DISLOCATIONS ON DIFFERENT (1 1 1) PLANES IS $\sim 70.5^\circ$.
- ▶ YONG YANG UW/ANL/UF



XAFS

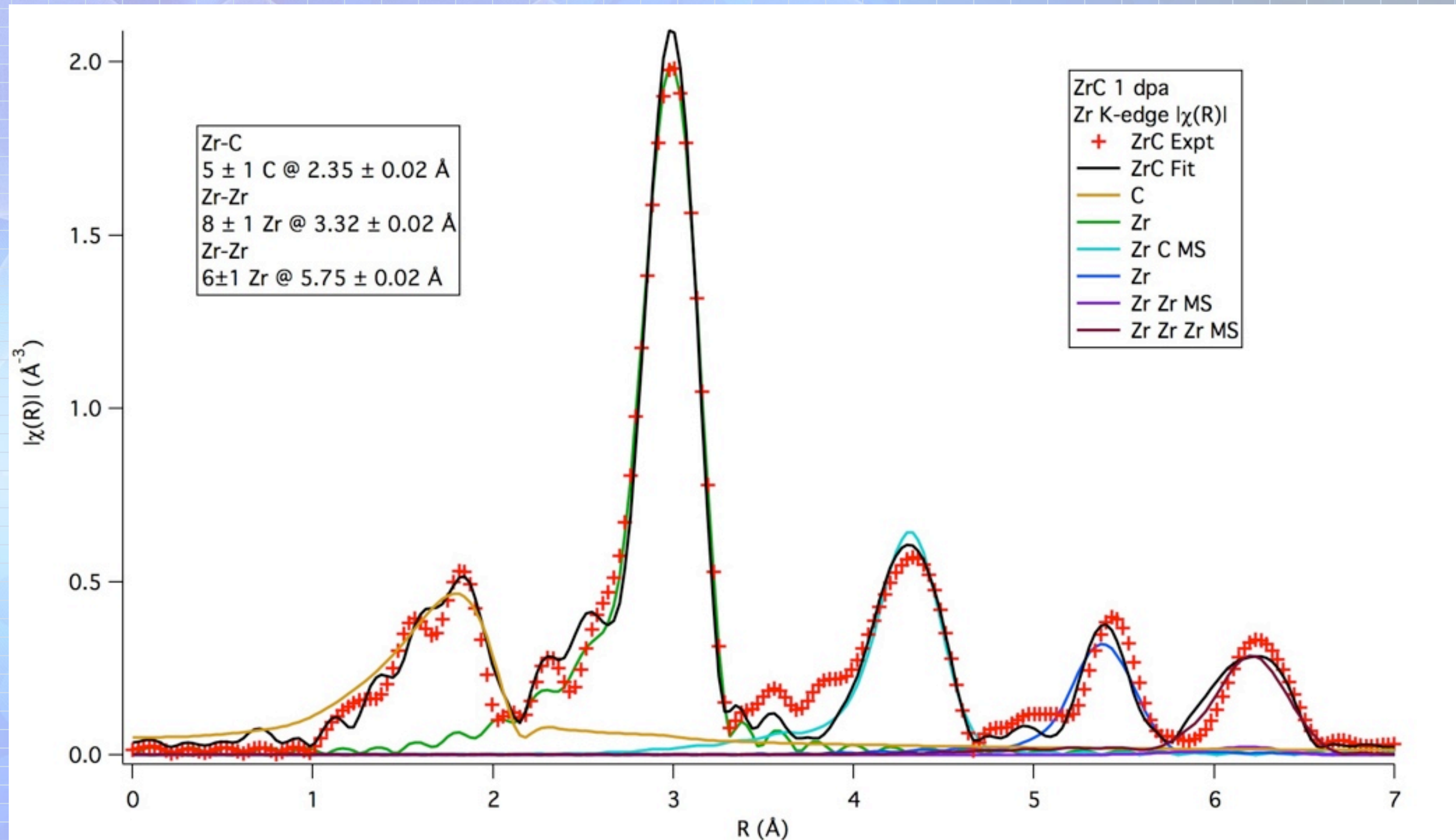


► DPA

► MULTIPLE SHELLS

► STRONG CRYSTALLINITY

XAFS



► 1 DPA

► MULTIPLE SHELLS

► STRONG CRYSTALLINITY

ZRC

► DISORDER

► σ^2 TERM

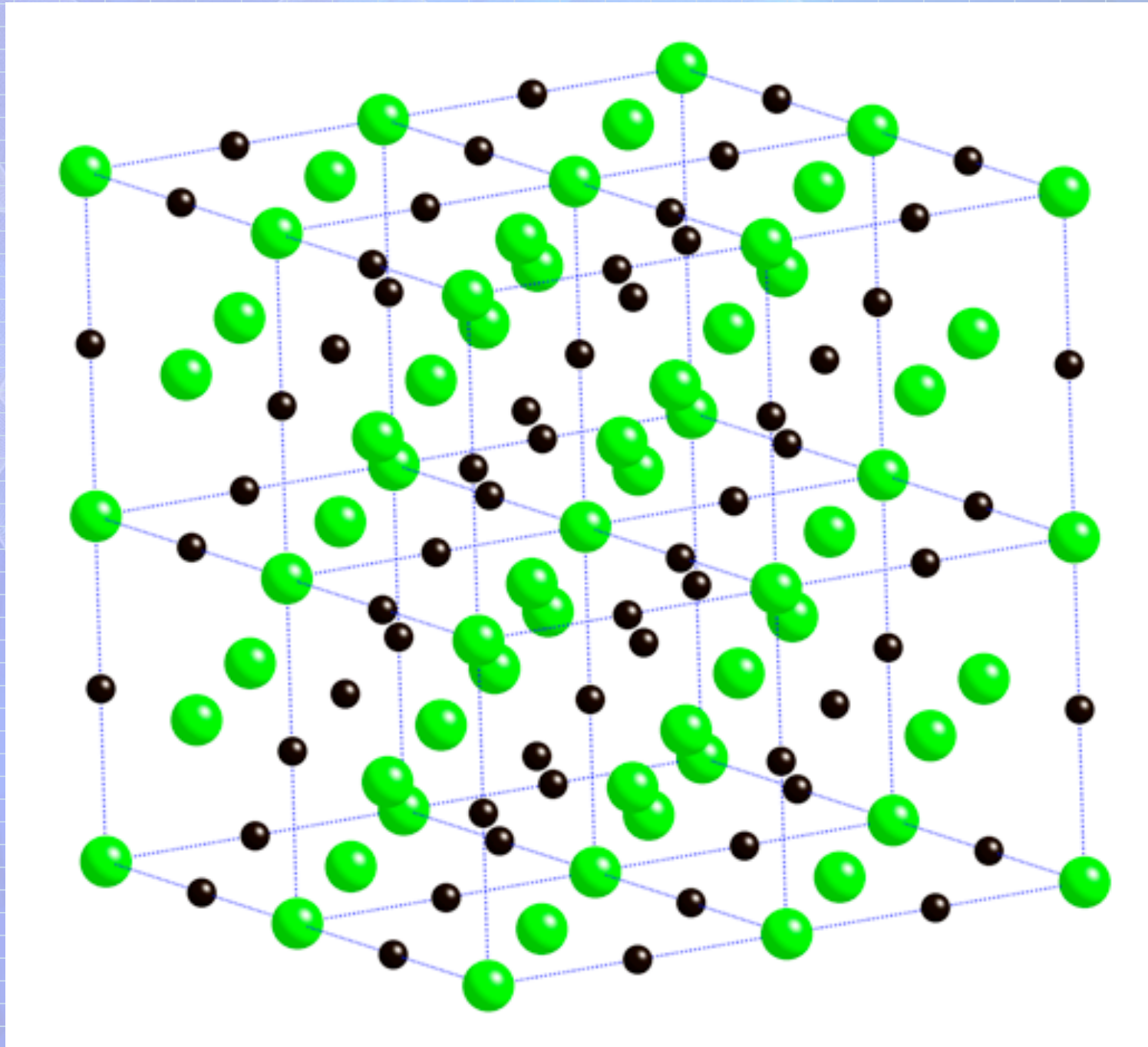
	ZRC	ZRZR	ZRZR
0 DPA	0.0007	0.0004	0.0003
1 DPA	0.0008	0.0004	0.0004

► SIZE

► N

	ZRC	ZRZR	ZRZR
0 DPA	5	9	9
1 DPA	5	8	6

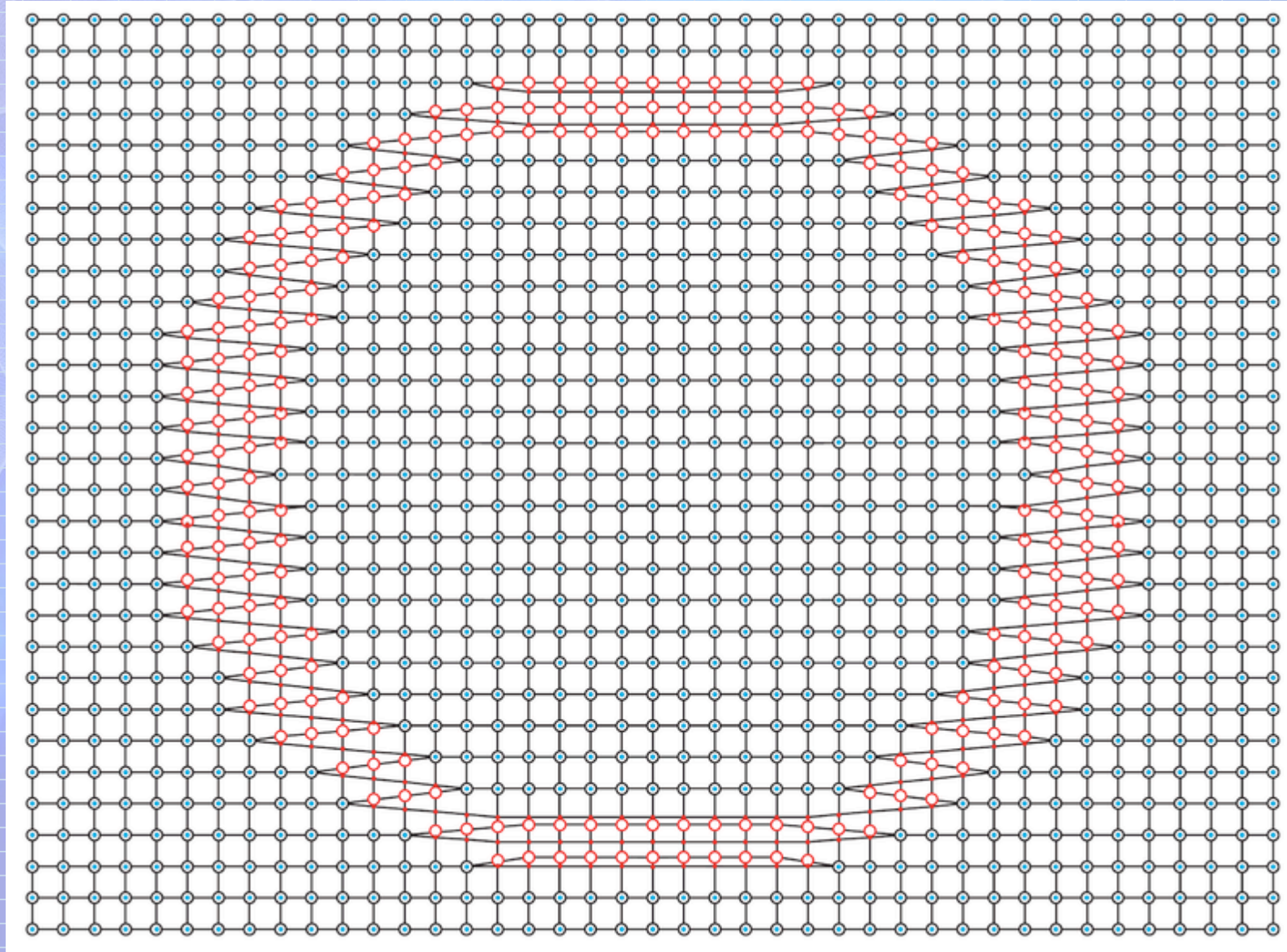
XAFS VS SIZE



▶ **SMALLER PARTICLES**

▶ **REDUCE COORDINATION**

ZRC



► **ROUGH (REALLY ROUGH) ESTIMATE**

► **UNDEFECTED REGIONS (10 NM DIAMETER)**

ZRC SIZE

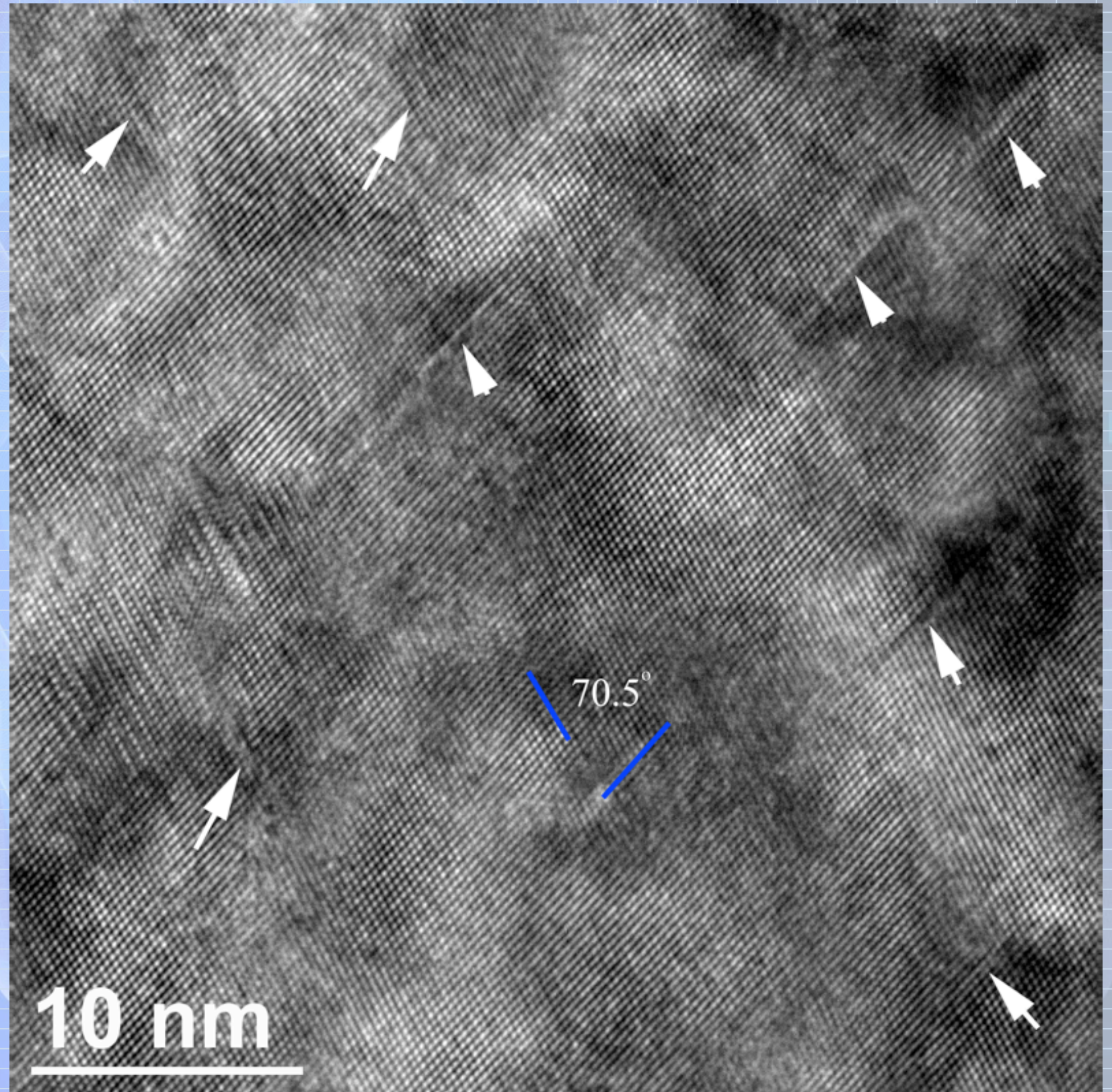
► 5 NM PARTICLE

► 2000 ATOMS

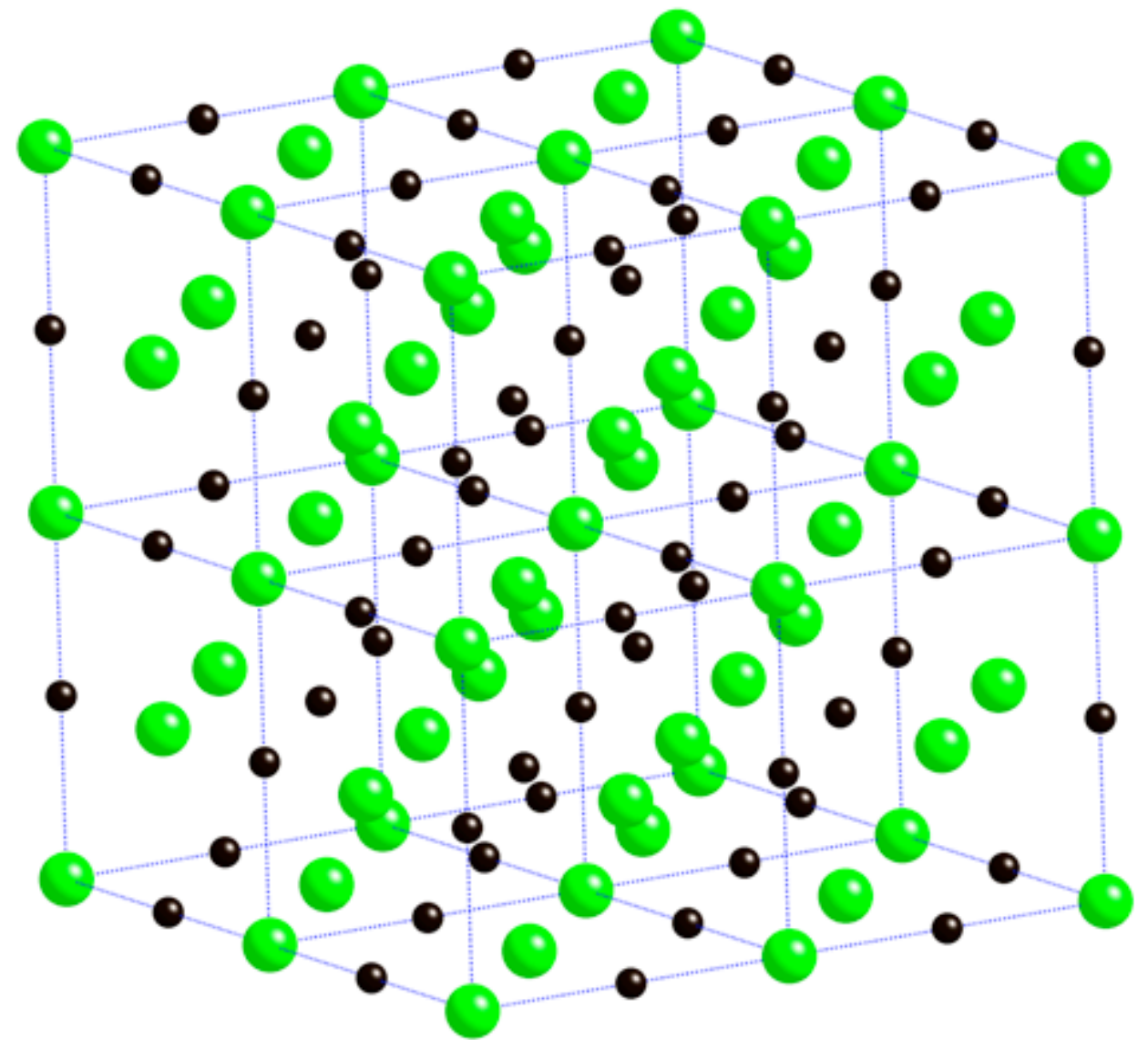
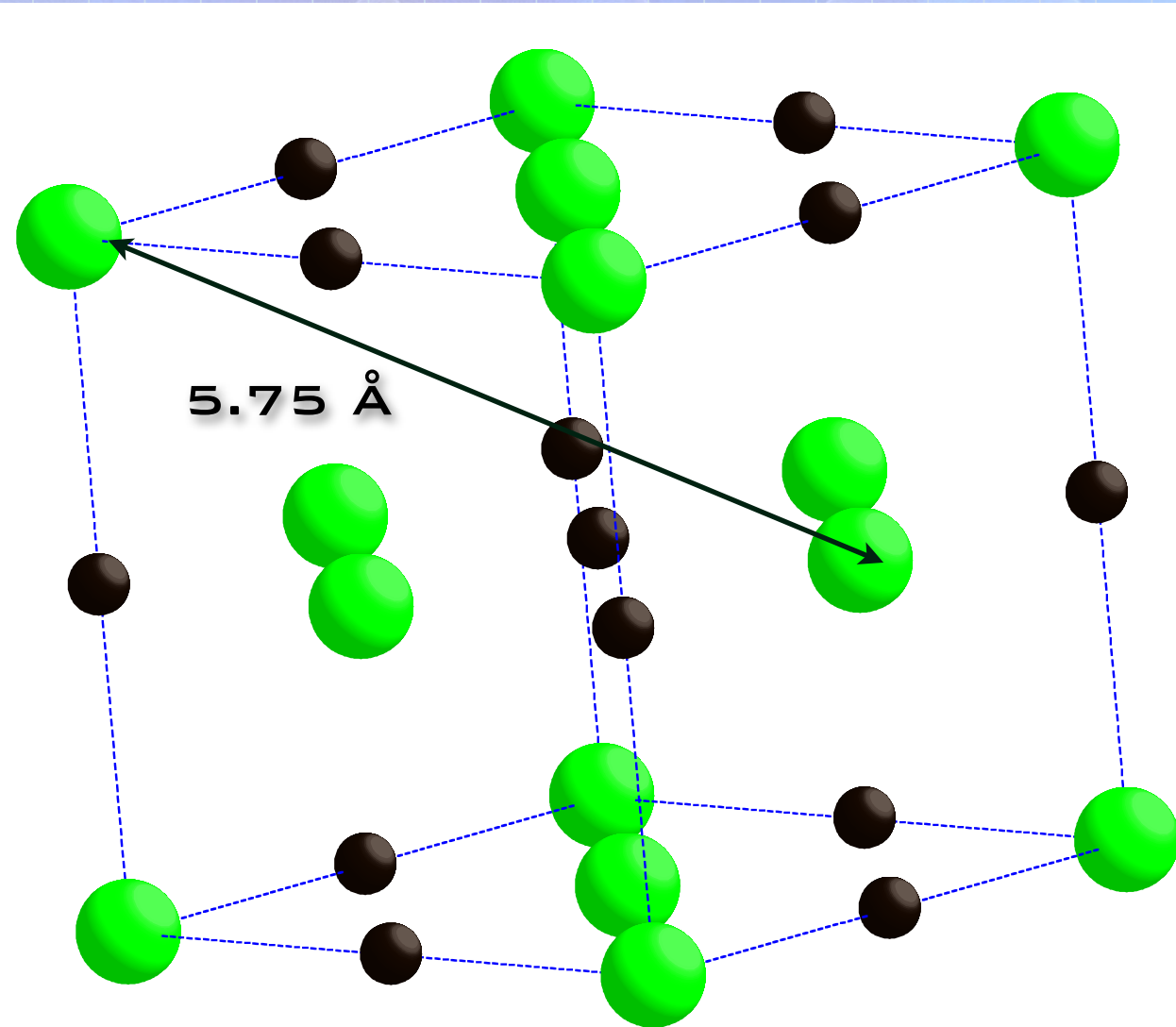
► 800 ATOMS SURFACE

► REDUCED
COORDINATION

► USE REDUCTION IN COORDINATION TO DETERMINE SIZE OF UNAFFECTED REGIONS

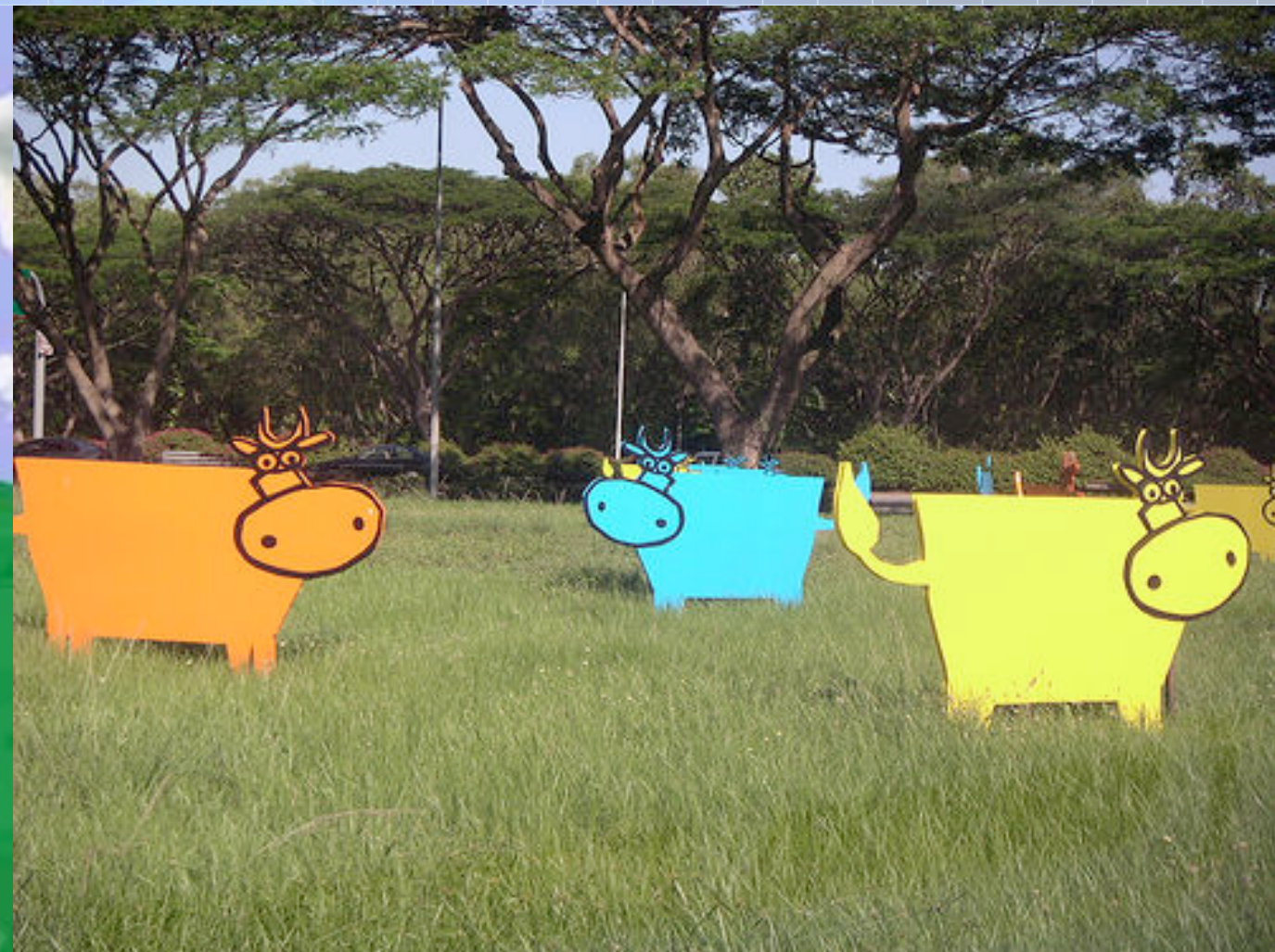


ZRC



▶ SEE SIGNIFICANT CHANGE (30 %) IN
COORDINATION AT 5.75 Å

ZRC



► MODELING

► SPHERICAL COWS

► PLANAR COWS

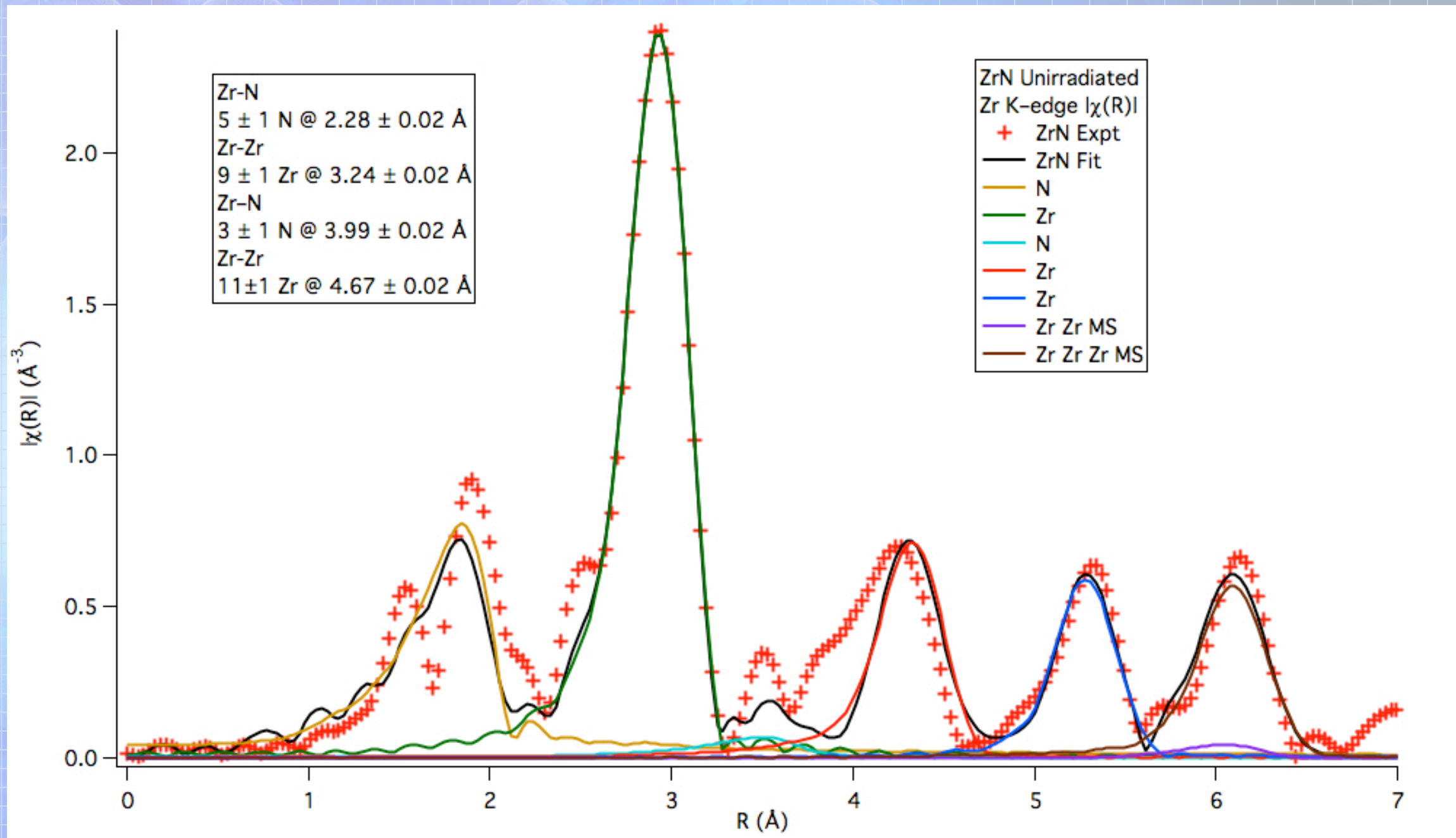
► BENEFIT FROM THEORETICAL GUIDANCE

ZRN

▶ **NOT AS FAR ALONG**

▶ **SIMILAR TRENDS**

ZrN XAFS

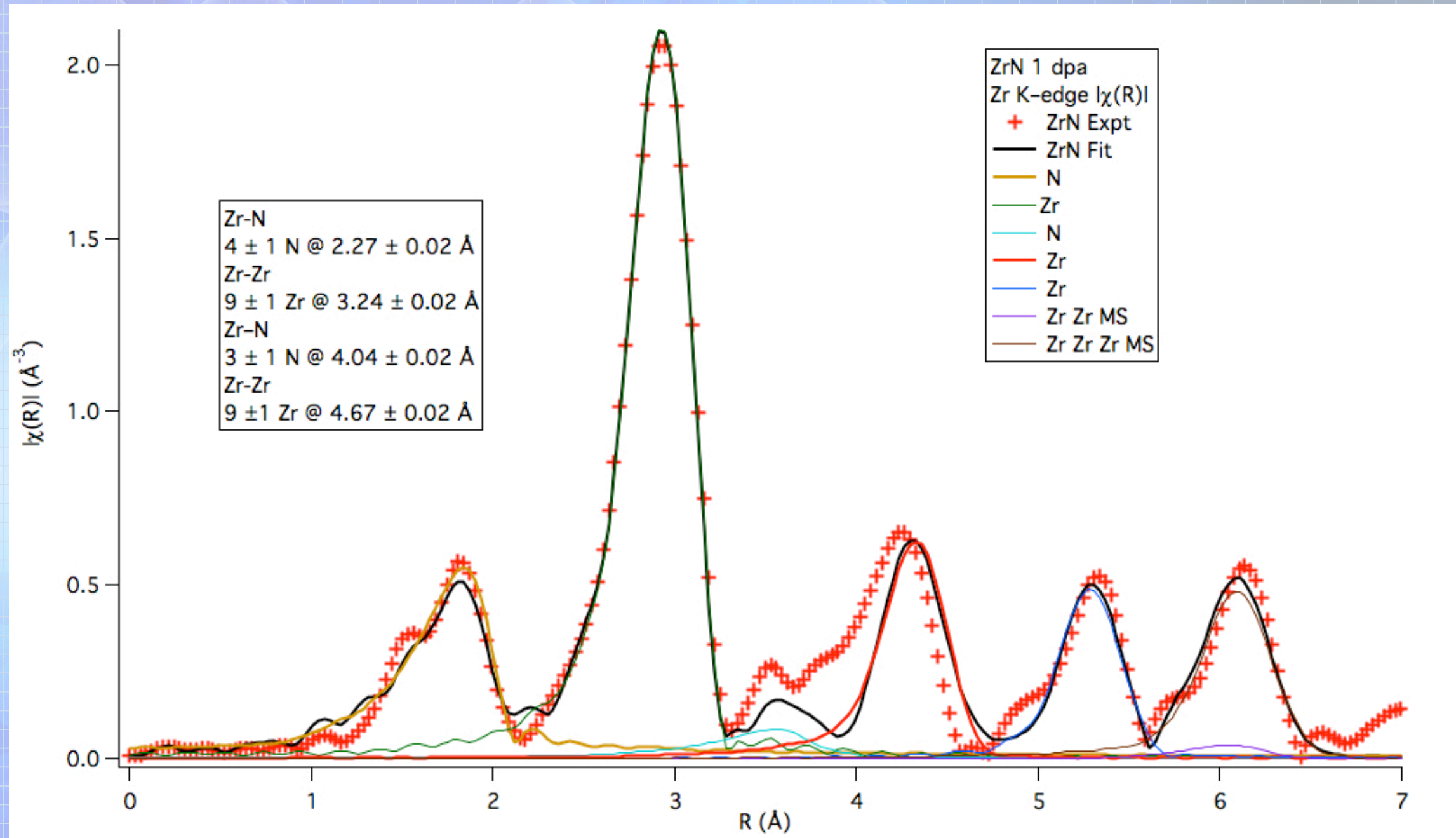


► DPA

► MULTIPLE SHELLS

► STRONG CRYSTALLINITY

ZrN XAFS

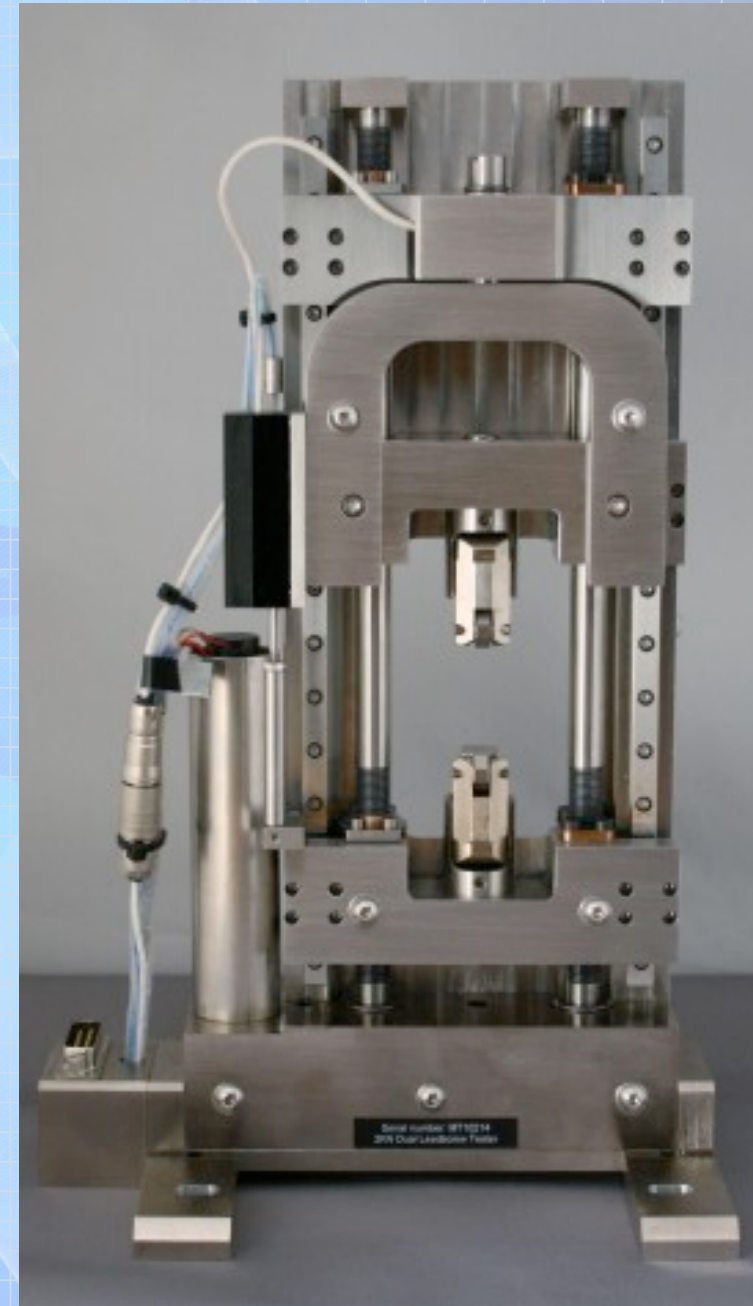


► 1 DPA

► MULTIPLE SHELLS

► STRONG CRYSTALLINITY

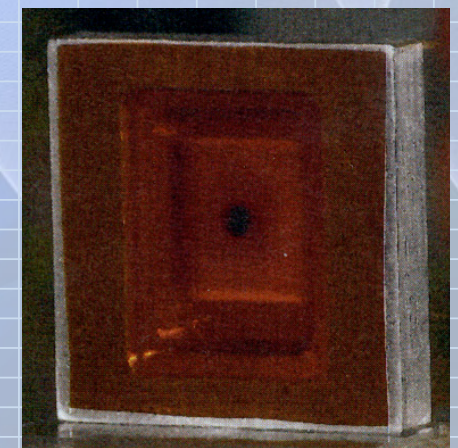
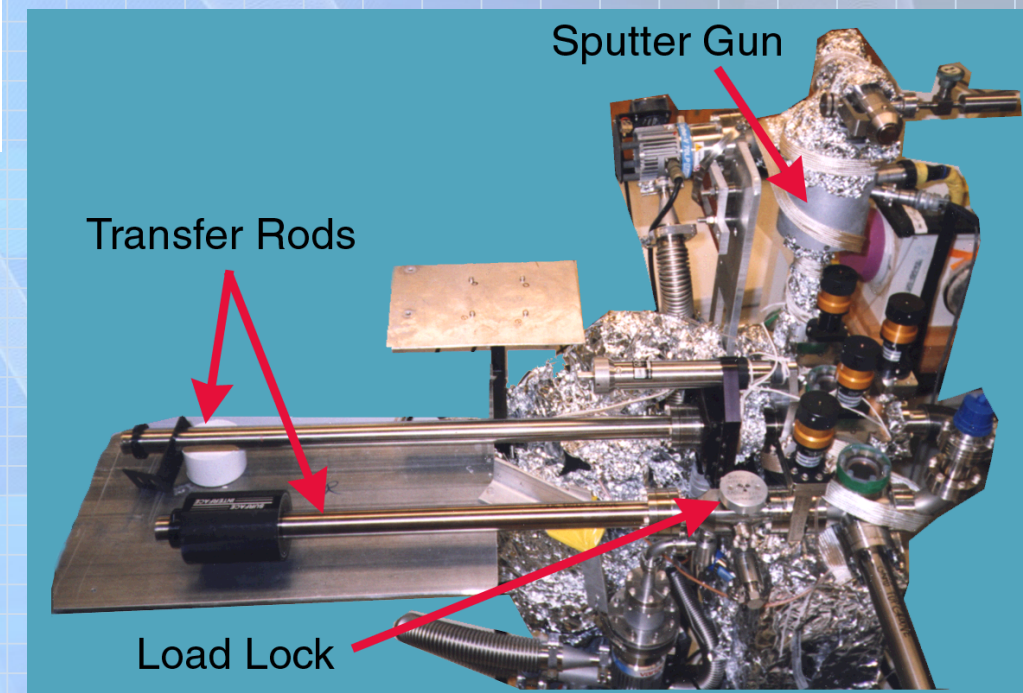
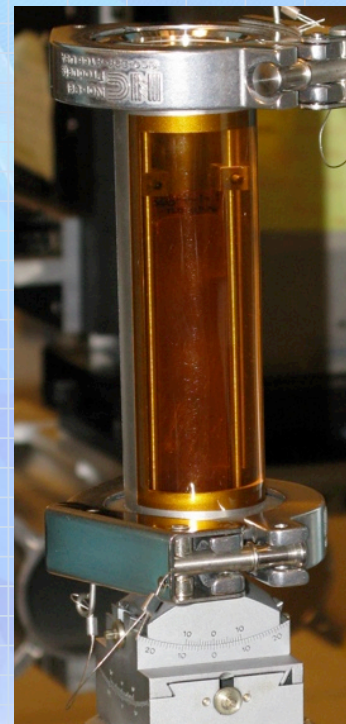
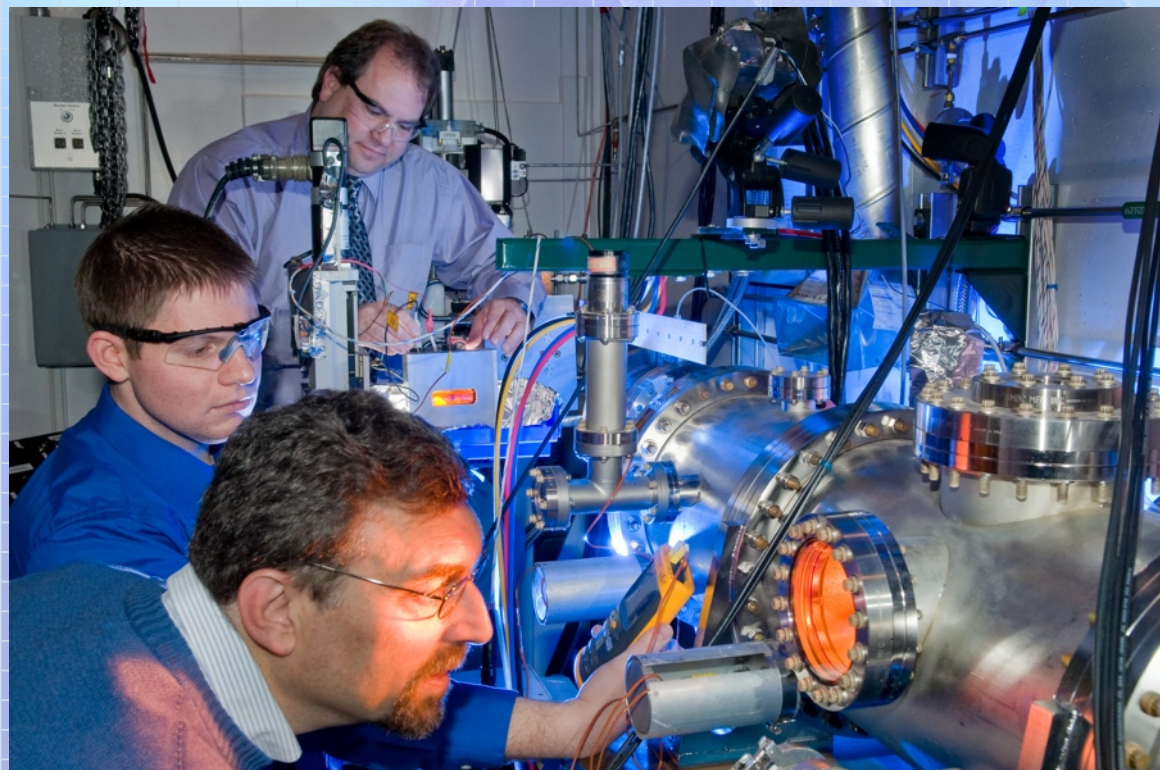
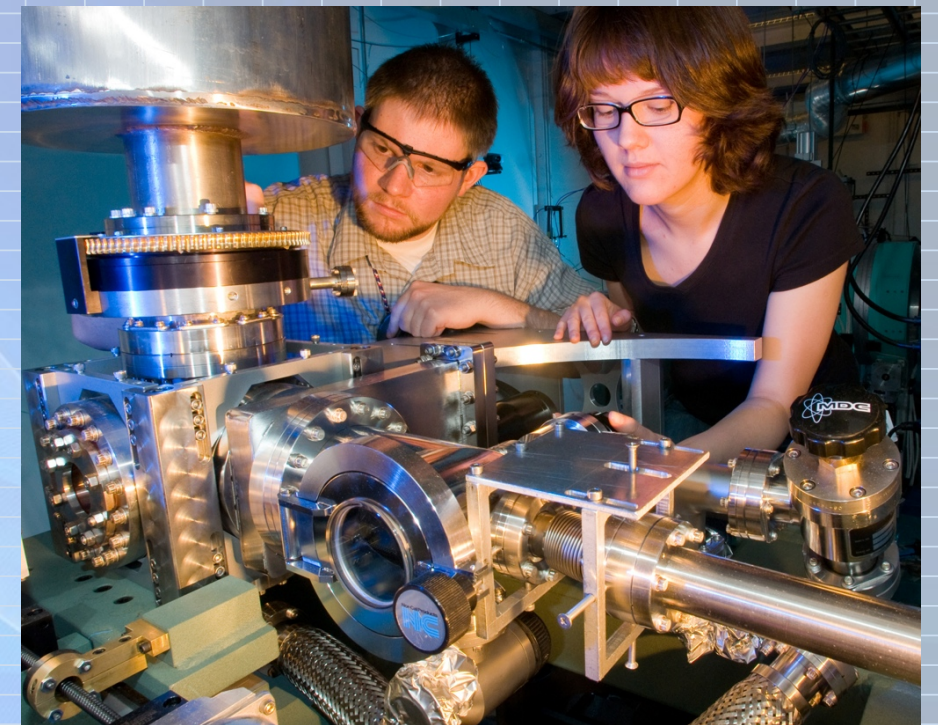
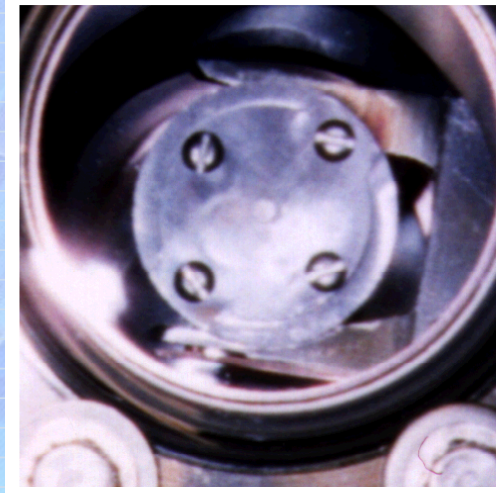
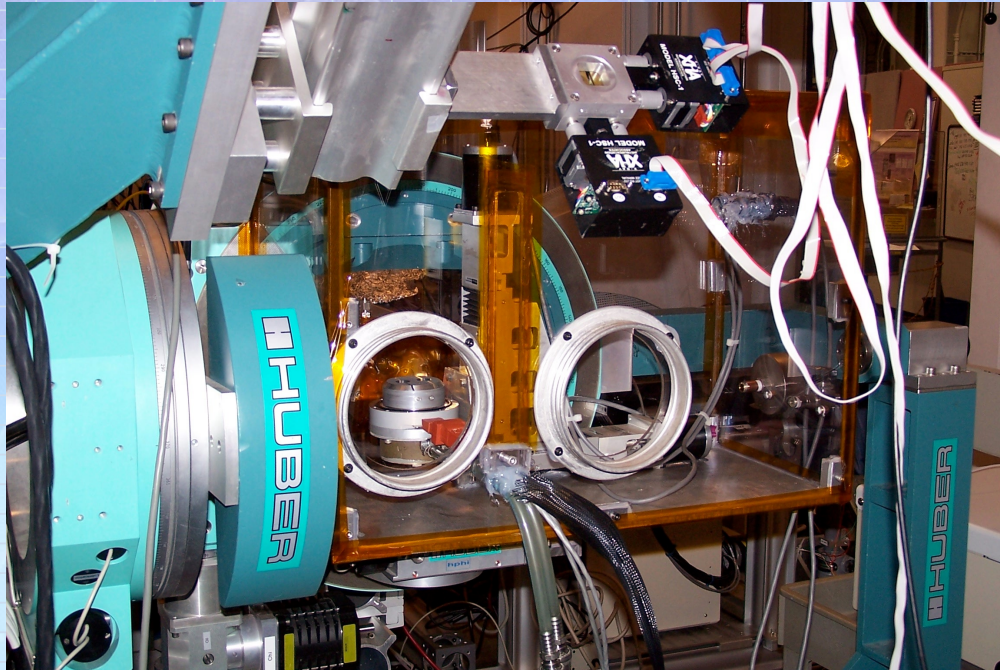
NEW EQUIPMENT



▶ 5 KN TENSILE STAGE

▶ LUKE WARM CELL

SAFETY



ACKNOWLEDGEMENTS

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